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Review Article

ARCHFORM IN ORTHODONTICS: A REVIEW

Amit Tiwari[1], Ashish Garg[2] , Bhavna Virang[3], Samprita Sahu[4], Neetu Shah[5], Nikhil Verma[6]

[1,2,3,4,5,6]MDS, Sri Aurobindo College of Dentistry, Indore(M.P.)

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ABSTRACT

Dental arch form is the arch, formed by the buccal and facial surfaces of the teeth when viewed from their occlusal surfaces. The universal ideal arch form is one of the most persistent but exclusive task for most of the orthodontic researchers have. Concerning the orthodontic treatment, basic principle of arch form in is that within reason, the patients original arch from should be preserved. Therefore, if the preformed arch wires are to be used, it is to be kept in the mind that their shape should be considered a starting point for the adjustment necessary for proper individualization as all the presently available preformed arch wire do not reflect these variations in the arch form. Because of these complex problems, and relatively low knowledge of dental arches, as of today, there is no universally accepted ideal arch form. The present article gives the review about the changes in the concept of arch form from conventional era to modern practice.

Introduction

Dental arch form is the arch, formed by the buccal and facial surfaces of the teeth when viewed from their occlusal surfaces. It is commonly believed that the dental arch form is initially shaped by the configuration of supporting bone. Following eruption of teeth and by circum oral musculature and intra oral functional forces.

HRDLICKA A. in 19161 conducted a study on normal dental arch and concluded that there is no such thing in existence, in any race that we know of, as one single normal dental arch; that in every race, and even under most normal conditions, we find a variety of arches which must be considered as normal arches and close attention should be paid to these fact as it has direct bearing on intelligent treatment of the patient.

Ideal arch form-

Percy N. William (1917)2 conducted a study to determine the shape of normal dental arch. He believed that arch form does not correlate with facial pattern. He did not agree that a round face indicated a round arch or a narrow face a narrow arch, etc. He disproved it by sending photographs of an individual along with a set of artificial teeth to ten of the leading practitioners of time, and asked them to arrange the teeth in an arch according to type. He received widely varying opinions which indicated that many practitioners had their own concept of what an ideal arch should look like which had no relation to the facial type of the patient.

He concluded from his studies that the front teeth should be arranged on a circle whose center is midway between the buccal grooves of the first molars. He also believed that the ratio of the widths between the

* Corresponding author***: Dr. Amit Tiwar, Sri Aurobindo College of Dentistry, Indore(M.P.), Email.add. dr.meet7590@gmail.com***

first molars and the cuspids should be maintained at approximately 14 to 9.

McCoy J D (1919)3 conducted a study on normal arch form and agreed with the concept of William that arch form was not dependent on facial type. He felt that careful observation would convince anyone to discard the theory that nature always produces teeth in harmony with face and features. He used as evidence several skulls which he claimed showed no relation of the forms of the teeth to the shapes or sizes of the skulls. Commenting on the methods of arch predetermination, he stated that use of any of the methods which were based on the amount of tooth substance contained within the arch, along with recognized anatomic principles, would render a greater service than the operator depending on his "Eagle Eye'" to guide him on his way.

Frederick L. Stanton (1922)4 devised a method of determining the ideal form of the arches of each case studied by using a map of the malocclusion and an “occlusal graph”, and then placing the teeth on charts in a manner to assure the best occlusion with the minimum tooth movement.

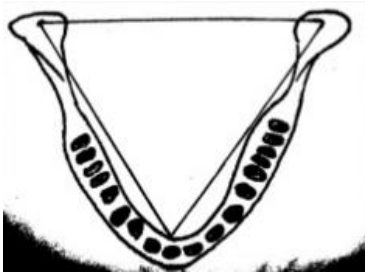
However, G. Izard (1927)5 believed that the dimensions of the dental arch were governed by the corresponding dimensions of the face. A constant ratio was found to exist between the width of the maxillary arch and width of the face, and between the length of the arch and depth of the face. He established the form of the maxillary arch as an ellipse, the large axis of which was determined by measuring the auriculo-incisal radius with a radiometer and the small axis by measuring the bizygomatic distance with a large compass and then subtracting the thickness of the soft tissue.

George C. Chuck(1934)6 conducted a study on ideal arch form and suggested that using the Bonwil1-Hawley arch as an aid in constructing a symmetrically formed alignment arch wire which could then be altered according to the type of the individual, while maintaining the symmetry of the arch wire.

Hassan Noroozi, Tahereh Hosseinzadeh Nik, Reza Saeeda, BS (2001) revisited the dental arch form. In their research, they tried to find the equation of a curve that would be similar to the generalized beta function curve and at the same time could represent tapered, ovoid, and square dental arches. A total of 23 sets of naturally well-aligned Class I casts were selected, and the depths and widths of the dental arches were measured at the canine and second molar regions. Using the mean depths and widths, functions in the form of $Y = AXm + BXn$ were calculated that would pass through the central incisors, canines, and second molars. Each function was compared with the generalized beta function with the use of root mean square values. It was shown that the polynomial function $Y = AX6 + BX2$ was the nearest to the generalized beta function. Then the coordinates of the mid-incisal edges and buccal cusp tips of each dental arch were measured, and the correlation coefficient of each dental arch with its corresponding sixth order polynomial function was calculated. The results showed that the function $Y = AX6 + BX2$ could be an accurate substitute for the beta function in less common forms of the human dental arch.

Tarcila Trivino, Danilo Furquim Siqueira, and Marco Antonio Scanavini. (2008)8developed a new concept of mandibular dental arch form with normal occlusion and concluded that the mandibular dental arch is represented by 23 forms; thus, a normal dental arch cannot be represented by only 1 simple arch form.

Shin-Jae Lee, Sungim Lee, Johan Lim, Heon-Jin Park, and Timothy T. Wheelere (2011)9 proposed a method to classify dental arch forms and they identified 3 types of arch forms, and cross-classification of the



BONWILL – HOWLEY ARCH FORM[14]

maxillary by mandibular arch forms showed a more frequent distribution in the diagonal elements than in the off-diagonal elements. It was concluded that by defining area discrepancies as distance measures and applying them to the cluster method by using medoids, the dental arch form can be classified keeping control for the extremes without bias.

BASIC TYPES OF DENTAL ARCH FORM 10, 11

Majority of them fall into one of the following types:

(1) Parabolic: It is shaped like a parabola, with an anterior curve and slightly diverging posterior legs.

(2) Hyperbolic: It is shaped like a hyperbola, with a flatter anterior curve and markedly diverging posterior legs.

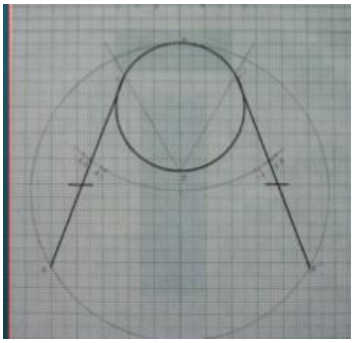
(3) Ellipsoidal: It is shaped like an ellipse with a curve anterior segment and slightly converging posterior legs.

(4) Square: It has a flat anterior segment and relatively parallel posterior legs.

(5) Omega: It has a curved anterior segment and posterior legs that converge then diverge

IMPORTANCE OF ARCH FORMS:

1) STABILITY: Robert M. Little, Terry R. Wallen, and Richard A. Riedel in 198112 did a study on Stability and relapse of mandibular anterior



alignment and concluded that Arch dimensions of width and length typically decreased after retention whereas crowding increased. This occurred in spite of treatment maintenance of initial intercanine width, treatment expansion, or constriction.

2) OCCLUSION: Unless the teeth are aligned in a proper arch form in both upper and lower arches, the occlusion will not be normal. Angle (1907)13 emphasised this with his concept of Line of Occlusion.

3) ESTHETICS: Primary reason for the patient to take treatment. Teeth arranged in proper arch form, will improve smile value as proposed by Sarver (2003).

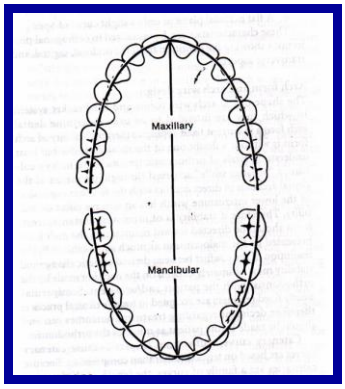
Different concepts of arch form:

BONWILL'S CONCEPT OF ARCH FORM

It was founded on the premise that the ideal arch should be based on an equilateral triangle. Bonwill established his triangle on the average width between the condyles which he found to be four inches.

Hawley felt that orthodontists could not measure the distance between the condyles accurately and, therefore, chose to base his arch on the width of the front teeth. The anterior form of the arch was that of a circle, the radius of which was the width of the central

and 1ateral incisors and the cuspid. The final form of the arch was established by the projection of two equilateral triangles which would vary according to the widths of the front teeth.



ANGLE'S LINE FOR OCCLUSION[13] in 1907 defined the line of occlusion as "the line with which in form and position according to type, the teeth must be in harmony i.e. in normal occlusion". He described this line as being more or less a parabolic curve which varied according to the race, facial type, temperament etc.

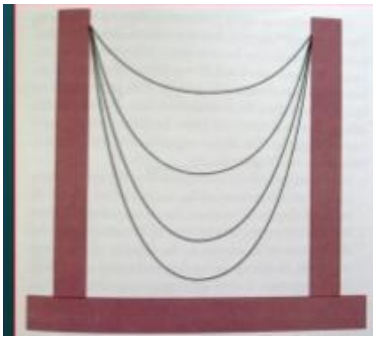
APICAL BASE CONCEPT:

It was proposed by Lundstorm.15 He highlighted the need to consider the apical base when determining the arch form for the patient. "Orthodontic experiments showed that a normal occlusion attained by mechanical treatment is not necessarily accompanied by a development of apical base in harmony with the position of the teeth, with the result that the occlusion cannot be maintained." "Occlusion doesn't control form and amount of apical base development but apical base is capable of affecting the dental occlusion"

CATERNARY ARCH FORM[16]

Concept first proposed by David Musich & James Ackerman (1973).

To measure the arch perimeter, they used an instrument that was a modified Boley Guage with a chain incorporated in it – CATANOMETER



Schulhoff (1997) used the same concept to describe the lower arch. Caternary curve is the shape that the loop of a chain would take if it were suspended from 2 hooks. Shape of the curve depends on the length of the chain and the distance between the hooks. When the width across the first molars is used to establish the posterior attachments, a caternary curve fits the dental arch form nicely for most individuals. Preformed archwires based on average intermolar dimensions.

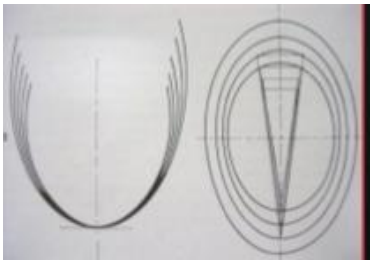
Bruide & Lilley17 found that the shape of basic bony arch at 9.5 weeks I.U, was caternary design. Caternary curve was made popular by work of McConail & Scher, who felt that from an engineering and biological point of view, the caternary curve was the simplest curve possible and could be easily explained mathematically

BRADER ARCH FORM[18]

The unique geometry of the curve representing superior dental arch form is approximated by a closed curve with trifocal elliptic properties, with the teeth occupying only a portion of the total curve at its constricted end. The primary determinants of arch form morphology are the (muscle) tissue forces of the

resting state in contradistinction to the intermittent forces of muscles in functioning states.

The geometry of the curve of dental arch form is so related with the resting forces of the tongue that PR=C, where:



Arch form from polynomial equation-

P = Pressure/unit area.

R = A radius of curvature at a point along the compound curve corresponding precisely with the pressure site.

C = A mathematic constant, exhibiting variation in magnitude between individuals, and variation in the same individual at different physiologic ages.

Arch form from polynomial equation-

Hayashi in 1962[44] used anatomical landmarks along the buccal cusps and incisal edges to study the curve of the dental arch. He found that the arch fit very well to the equation $y=ax^{n} +- e^{a(x-b)}$. **Hayashi** assumed symmetry of the arches and, therefore, looked at only one side of the arch.

K. H. Lu, 1966[20] felt that Hayashi's method was too cumbersome. **Lu** suggested the use of orthogonal polynomials for fitting equations to arch form. The even- powered polynomials measured the symmetry of the arch and the odd- powered the asymmetry He found that the fourth degree polynomial fit the arch form quite nicely.

James H. Currier in 1969[21], used a generalized polynomial least squares curve- fitting program to compare the ellipse and parabolas to 25 pairs of plotted dental arch curves. Statistical analysis of the result showed that the ellipse provided a better goodness of (smaller variance) for the maxillary outer (facial) dental arch curve than the parabola, while the parabola provided a better fit to the mandibular middle curve than did the ellipse.

The ellipse had a total smaller variance of fit to the outer curves in the maxillary and the mandibular arches, while the parabola had a total smaller variance of fit to the middle curves in both the arches. Because most present –day orthodontic procedures are performed on the outer (facial) surfaces of teeth, it was concluded that the ellipse is the better guide to arch form than the parabola.

Susan H. Pepe in 1975[22], fit polynomial and catenary equations to the dentitions of seven children with normal occlusion. She found that **neither catenary nor polynomial curves** fit the dental arch well enough to serve as a template for an arch wire. The catenary fit the arch form least accurately. She also found that the 6th degree polynomial equations afforded significant increase in accuracy of fit over the 4th degree, which had been suggested for use by Lu. She felt that the 6th degree polynomial had potential as clinical indicators of arch form and perhaps malocclusion. She suggested that spline curves may also be found to have a high degree of accuracy of fit.

Seba AlHarbia; Eman A. Alkofideb; Abdulaziz AlMadic, in 2008[23] did a mathematical Analyses of Dental Arch Curvature in Normal Occlusion and found out that the polynomial function (fourth order) was found to be a reasonable analysis when the objective is to describe the general smooth curvature of the dental arch, while a Hermite cubic spline is more appropriate

when it is desired to track arch irregularities, such as evaluating treatment changes. It was concluded that due to its advantage in providing a more naturally smooth curve, the fourth-order polynomial function may be used as a guide to fabricate customized arch wires, or even an entire fixed orthodontic appliance system.

Kazuhito Arai and Leslie A. Will in 2011[24] evaluated the relationship between subjective classification of dental-arch shape, objective analyses via arch-width measurements, and the fitting with the fourth-order polynomial equation. It was concluded that Subjective clinical assessments were generally in agreement at the extremes of tapered and square arch forms; the exceptions were arches with an ovoid shape. There were statistically significant correlations between subjective dental-arch classifications and dental-arch dimensions, as well as the ratio determined from these variables and polynomial equation analyses. Therefore, fourth-order polynomial equations might be an important factor in the quantitative analysis of dental-arch form in orthodontic patients.

ROCKY MOUNTAIN DATA SYSTEM

ROCKY MOUNTAIN DATA SYSTEM computer derived formula relies upon measurements taken from inter molar width, inter cuspid width and arch depth as measured from the facial surface of the incisors to the distal surface of the terminal molar. This allows computer to be programmed with Cartesian X & Y co-ordinates that are necessary for arch computation. Facial type is also considered arch design applicable only to the lower arch

White in 1978[25], compared arch forms derived From four basic designs the **Bonwill-Hawley, the Brader, the catenary, and the Rocky Mountain Data Systems computer derived formula**. His subjective opinion of their fit to 24 untreated superior adult occlusions was:

1) The catenary design had agood fit for 27% of the arches while the other three varied form 8-12%;

2) the R.M. D. S. computer-derived arch yielded 92% moderately good fit with no poor fits,

3) the Bonwill Hawley, Brader, and catenary curves had between 40-46% moderately -derived good fits with forms 27 to 52% poor fits. "The catenary and R.M.D.S computer derived arch forms were superior overall to the Brader & Bonwill-Hawley designs, **White** suggested that the lack of fit was due to asymmetry of the arches.

INDIVIDUALIZED IDEAL ARCHES[25]

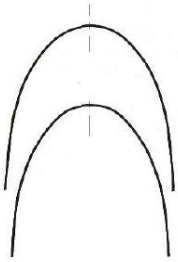
Proposed by Larry White in 1978. Undertook a study to see how a collection of ideal, untreated arches conformed to the predetermined arch forms of the most popular formulae. Models of 24 orthodontically untreated superior, adult occlusions were collected and tracings made on acetate paper & overlays were superimposed. The closeness of fit was evaluated and graded as ‘good fit’, ‘moderately good fit’ and ‘poor fit’.

RICKETTS PENTAMORPHIC ARCH FORMS[26]

Considered the following factors in the determination of the arch form: Arch correlation, size, arch length, where the arch was measured, contact details and form at the bracket location. Originally 12 arch forms were identified from different studies. These were narrowed to 9 by computer analysis. Studies of other normal and stable treated patients resulted in elimination of all but 5 forms. These pentamorphic arch forms were such that they would fit most facial forms

RESEARCH ARCH FORM/ CLINICAL ARCH FORM

Acc. To McLaughlin & Bennet, there is a difference between the clinical and research arch form. Braun et al



Taperd Arch Form

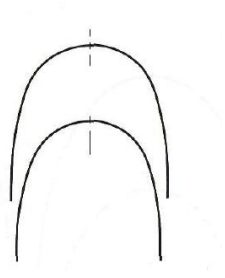
(1966)[27] represented arch form by a complex mathematical formula known as "Beta Function". They measured the centre of each incisor incisal edge, cusp tips of canines and premolars and the M-D and D-B cusp tips of molars. This research arch form can be surprisingly tapered. In contrast clinicians arch wire shape must be based on the points where the wire will lie in the bracket slots of correctly positioned brackets. This arch form relates to the mid-point on the labial surface of the clinical crowns of the teeth, and should include estimation for the in out which is built into the bracket system.

MBT ARCH FORM[28]

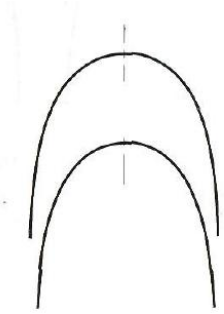
The three basic arch forms are tapered, square and ovoid. When superimposed they vary mainly in inter-canine width, giving a range of approximately 6mm. Inter-molar widths are similar, but the molar areas can be widened or narrowed as needed, by easy wire bending.

THE TAPERED ARCH FORM

This arch form provides the narrowest inter-cuspid width & Indicated for patients with narrow, tapered arch form and gingival recession in canine and premolar regions. Cases undergoing single arch treatment, in this way no expansion of treated arch occurs. The posterior part of this arch form can easily



Square Arch Form



Ovoid Arch Form

be modified to match the inter-molar width of the patient.

THE SQUARE ARCH FORM

Indicated in cases with broad arch form and cases that require buccal uprighting of the lower posterior segments and expansion of the upper arch. After over-expansion has been achieved, it may be beneficial to change to the ovoid arch form in the later stages of treatment. The square arch form is useful to maintain expansion in upper arches after rapid maxillary expansion.

THE OVOID ARCH FORM

It is the most preferred arch form. The ovoid arch form has proved to be good, reliable arch form for high

percentage of cases treated. Treated cases have shown good stability, with minimal amounts of post-treatment relapse. When superimposed, the three shapes vary mainly in inter-canine and inter-first premolar width, giving a range of approximately 6 mm in this area.

Arch Form in Lingual Orthodontics

Due to the lingual morphology of the teeth, a straight wire cannot be engaged lingually. The arch wire form is changed accordingly. The wires used here are "Mushroom Shaped", with an offset present between canine and premolar. During sliding mechanics, there is a transverse bowing of the arch leading to distortion of the arch form. To prevent this posterior legs of the archwire are bowed outward to compensate for the transverse bowing of the arch. Andreiko (1994) asserted that shape of the mandible should dictate the arch form, with the teeth theoretically aligned and contained within the limits of mandibular bone. The arch forms are derived from the skeletal and dental anatomy and are therefore designed to be closer to an anatomic ideal than a mathematical ideal. Previous arch wire shapes had them in the concept of an ideal arch form; anatomy probably was not given enough consideration in design.

The appeal of the newer approach includes the following.

1. Arch forms are derived from the skeletal and dental anatomy and therefore are designed to be closer to an anatomic ideal than a mathematical ideal.

2. Individualized treatment is simplified.

3. This works by scanning models of the patient's dentition to a resolution of 50μm or 0.002 inch. With a three-dimensional control interface the clinician has the capability of specifying exactly how each tooth is oriented as it moves to the desired position and can design arch shape as desired, within the parameters of the scanned limits of the buccal and lingual cortical plates.

4. Once the patient's customized occlusal scheme is finalized, the data from the setup then is drawn on by the CAD-CAM machinery to cut each bracket to individual specifications for that patient, and the arch wires also are manufactured to the specifications set by the clinician.

CONCLUSION

The universal ideal arch form is one of the most persistent but exclusive task for most of the orthodontic researchers have. Although literature review illustrates divergent views on the shape of arch form, it is now generally believed that the arch shape is determined by an interplay between genetic and many varied environmental factors such as pressure from soft tissues; shape and position of jaws; alteration in eruptive mechanism and morphology of teeth. Concerning the orthodontic treatment, basic principle of arch form in is that within reason, the patients original arch from should be preserved. Therefore, if the preformed arch wires are to be used, it is to be kept in the mind that their shape should be considered a starting point for the adjustment necessary for proper individualization as all the presently available preformed arch wire do not reflect these variations in the arch form. Clinicians should therefore be cautious when treating individuals to a mathematically derived ideal. Because of these complex problems, and relatively low knowledge of dental arches, as of today, there is no universally accepted ideal arch form. The irony of wisdom is that, the more we know about a

particular subject, the more our ignorance unfolds and the goal seems far ahead.

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